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Double Charged Higgs Bosons Production in e^-e^--Collisions

R.A.Alanakyan

Theoretical Physics Department, Yerevan Physics Institute, Alikhanian Brothers St.2, Yerevan 375036, Armenia

E-mail: Alanak @ vx1.YERPHI.AM

Abstract

In the framework of the models with Higgs triplets, double charged Higgs bosons production in the processes $e^-e^- \to \delta^{--}_{L,R}\gamma$ are considered.

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Double charged Higgs bosons arise in theories with Higgs sector enlarged by triplets of Higgs bosons(see e.g. [1] and ref. therein).Their introduction provides a natural explanation of the smallness of the left neutrinos masses. Double charged Higgs bosons and Majorana neutrinos lead to some new phenomena such as neutrinoless β -decays, $\mu \to 3e$ decay, muonium-antimuonium conversion and other processes with lepton number violation [2, 3].

In particular, in [2, 4] the process:

$$e^-e^- \to \mu^-\mu^- \tag{1}$$

mediated by $\delta^{--}_{L,R}$-bosons and the processes [4, 5]:

$$e^-e^- \to W^-_{L,R}W^-_{L,R} \tag{2}$$

mediated by double charged Higgs bosons or (and) heavy Majorana neutrino have been considered. High energy and high luminosity e^-e^--colliders in particular e^-e^--version of NLC and TLC colliders have been considered in [6, 7].

Here we study double charged Higgs boson production in the processes

$$e^-e^- \to \delta^{--}_{L,R}\gamma, \tag{3}$$

described by three diagrams on Fig.1. Produced $\delta^{--}_{L,R}$-bosons may decay into l^-l^- or into $W^-_{L,R}W^-_{L,R}$-pairs if it is kinematically possible [1].

Using formula (A5) in Appendix A for $\delta^{--}_{L,R}$-interaction with electrons we obtain the following gauge invariant amplitude of the process (3):

$$M = 2eh_{ee}\bar{u}(k_1)\left(\frac{\hat{k}_4\hat{A}}{(k_2-k_3)^2} + \frac{\hat{A}\hat{k}_4}{(k_1-k_3)^2} + 4\frac{(k_4A)}{s-m_H^2}\right)P_{L,R}u^c(k_2) \tag{4}$$

Here we neglect electron mass and use the following notations: A_μ is the polarization 4-vector of the photon, $s=(k_1+k_2)^2$, m_H is the mass of δ^{--}_L or δ^{--}_R-bosons.

For differential cross section we obtain the following result:

$$\frac{d\sigma}{d\cos\theta} = \frac{\alpha h_{ee}^2}{s}\left(1+\frac{2(1-\beta)}{\beta^2}\right)\beta ctg^2\theta \tag{5}$$

Here θ -is an angle between photon momentum $\vec{k_3}$ and electron momentum $\vec{k_1}$, $\beta = \left(1-\frac{m_H^2}{s}\right)$ is the velosity of $\delta^{--}_{L,R}$-boson in the c.m. system.

We see that our result contains collinear singularity at $\theta = \pm 0$, and we cut some cone near this direction as it has been done for $e^+e^- \to Z^0\gamma$ process (see [8] and references therein).

The cross section of the process (3) as well as cross section of the process $e^+e^- \to Z^0\gamma$ contain also infrared singularity near reaction threshold.

Number of events $\delta^{--}_{L,R}\gamma$ per year (σL) is shown on Fig.2 at $\sqrt{s} = 0.5, 1$ TeV and luminosity $L = 10^{41} sm^{-2}$. We use cut $|\cos\theta| < 0.9$ and 0.95.

Thus we see that consideration of the process (3) may provide new restriction on the h_{ee} and m_H in addition to the restriction from nonobservation of above mentioned low energy processes with lepton number violation, anomalous muons magnetic moment and Bhabba scattering [1]-[3].

Let us compare the cross section of the process (1) and (2) with the cross section of the studied process (3).

The process $e^-e^- \to W_R^- W_R^-$ will be kinematically forbidden for large masses of $W_R^{\pm}$-bosons $(2m_{W_R} > \sqrt{s})$.

The process $e^-e^- \to \delta_L^{--*} \to W_L^- W_L^-$ may be suppresed by smallness of the vertex $W_L^- W_L^- \delta_L^{++}$ .For instance, in left-right models this vertex is suppressed by factor $\frac{v_L}{k_L}$ which is small for preserving true relation between $W_L^{\pm}$,Z^0-bosons masses and Weinberg's angle.

The cross section of the process (1) is of order $h_{ee}^2 h_{\mu\mu}^2$ whereas the cross section of the studied process is of order h_{ee}^2, so the cross section of the process (3) at small $h_{\mu\mu}$ and far from resonanse (i.e. far from range $\sqrt{s} = m_H$) may dominate over reaction (1).

It must be noted, that all our results are also applicable for a more general case where Yucawa couplings of the left triplet and right triplet with left- and right-handed leptons are different.

Appendix A

In the left-right symmetric model the interaction of left and right triplets with ($Y = 2$) of Higgs bosons:

$$\Delta_{L,R} = \begin{pmatrix} \delta^{+}_{L,R}/\sqrt{2} & \delta^{++}_{L,R} \\ \delta^{0}_{L,R} & -\delta^{+}_{L,R}/\sqrt{2} \end{pmatrix} \tag{A.1}$$

with left- and right-handed lepton fields $\psi^T_{L,R} = (\nu^T_{L,R}, e^T_{L,R})$ are described by lagrangian:

$$\mathcal{L} = ih_{ij}\left(\psi^T_{iL} C\tau_2 \Delta_L \psi_{jL} + \psi^T_{iR} C\tau_2 \Delta_R \psi_{jR}\right) + h.c. \tag{A.2}$$

Here i,$j = e, \mu, \tau$-are generations indices, C is the charge conjugation matrix, τ_2 is the Pauli matrix. After symmetry breaking Majorana masses of the heavy approximately right handed neutrinos are expressed through the Yucawa couplings h and neutral component of right triplet vacuum expectation v_R in the following way:

$$m_N = \sqrt{2} h v_R \tag{A.3}$$

Also, large right triplet vacuum expectation ($v_L \ll k_L$,$k_R \ll v_R$, k_L, k_R- are vacuum expectations of the left and right doublets, v_L-vacuum expectation of the left triplet)

provide mass of the $W^{\pm}_R$-bosons:

$$m_{W_R} = \frac{1}{2} g v_R \tag{A.4}$$

whereas doublet vacuum expectation is responsible for mass of $W^{\pm}_L$-bosons.

So, as seen from (A3),(A4) in left-right symmetric models Yucawa couplings h are expressed through the m_{W_R} and m_N.

From (A1), (A2) $e^- e^- \to \delta^{--}_{L,R}$ transition is given by amplitude:

$$\mathcal{M} = 2h_{ee}\bar{u}(k_1) P_{L,R} u^c(k_2) \tag{A.5}$$

where $u^c = C\bar{u}^T$,k_1, k_2-are momenta of the two electrons.

In general, mass matrix of $\delta^{--}_{L,R}$ bosons is nondiagonal, however in the limit $v_L \ll v_R$ mixing between δ^{--}_L and δ^{--}_R is negligible.

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Figures captions:

Fig.1 Diagramms corresponding to the processes $e^-e^- \to \delta^{--}_{L,R}\gamma$.

Fig.2 Number of events $\delta^{--}_{L,R}\gamma$ per year (at $L = 10^{41} sm^{-2}$) produced in reaction (3) as a function of m_H at $h_{ee} = 10^{-2}$.Solid lines 1,2 correspond to the energies $\sqrt{s} = 0.5, 1$ TeV and cut $|\cos\theta| < 0.9$.

Dotted curves 3,4 correspond to the energies $\sqrt{s} = 0.5, 1$ TeV and cut $|\cos\theta| < 0.95$.

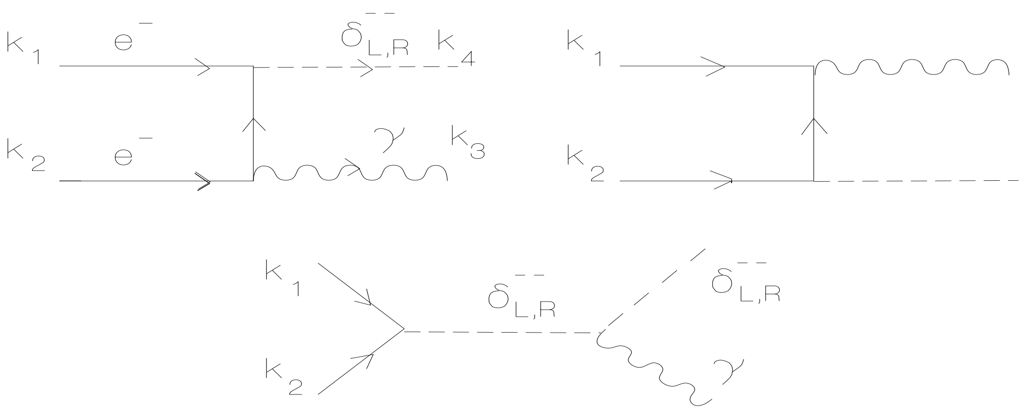
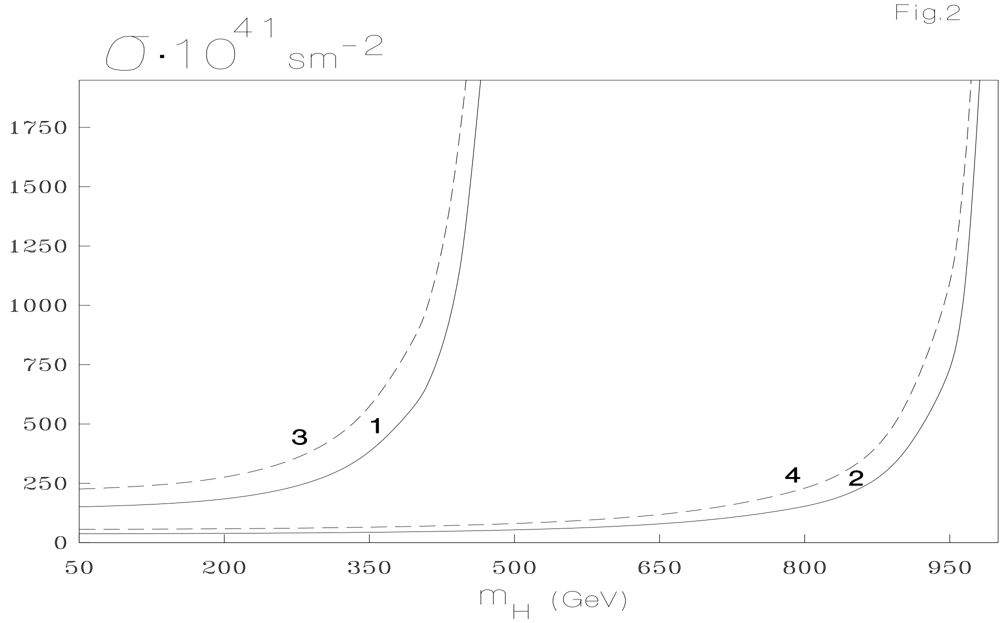


Fig.1

Fig.2


σ·10^41 sm^-2
1750
1500
1250
1000
750
500
250
0
50
200
350
500
650
800
950
m_H (GeV)
3
1
4
2